MONTHLY WEATHER REVIEW

Editor, EDGAR W. WOOLARD

VOL. 70, No. 6
W. B. No. 1363

JUNE 1942

CLOSED AUG. 3, 1942
ISSUED SEPT. 12, 1942

THE HEAVY RAINS OVER SOUTHEAST TEXAS, NOVEMBER 22–25, 1940

By JAMES H. FERGUSON

[Weather Bureau, Fort Worth, Tex., April 1941]

The paper gives a three-dimensional picture of the meteorological conditions over the southern United States during November 21 to 25, 1940, inclusive. The air-mass designations are based on those of the Bergeron [1] classification as modified by Willett [2] and Showalter [3]; Showalter's values for autumn are used. The isentropic cross sections are similar to those used by Pierce.[4] The method of locating fronts is that suggested by Rossby [5] and Willett [6]: "* * * true air-mass boundaries must coincide with isentropic surfaces." The isentropic condensation temperature is used for determining the amount of lift that a front will create, using winds aloft to show the air flow along constant potential temperature (or isentropic) surfaces; the isentropic condensation temperature of a mass of air is defined as the temperature it would have if it were raised adiabatically without gain or loss of water vapor to the condensation level.[7] The advantages of this type of cross section are shown by Pierce [8] to be: first, there are a less number of lines on the cross section; second, convective instability is roughly shown; third, amount of lift necessary for condensation is easily found; fourth, fronts are easily found; fifth, all isentropic surfaces are shown; and, finally, the nearness to saturation at any point can be determined.

On the synoptic map of November 21, 1940, at 1:30 a. m., E. S. T. (fig. 1a), a cold front extended from a weak LOW center of approximately 1010.5 mb. (29.84 inches) in eastern Kansas southward to central East Texas, near Laredo. The cold front was developing definite quasi-stationary characteristics in the interior of southeast Texas, which were indicated by rapidly falling pressure tendencies to the northwest of the front over central and northwest Texas. As will be shown later, these falls were significant according to Norton,[9] Petterssen [10] and others, who have pointed out that when a cold front slows down or becomes quasi-stationary its characteristics often change from those of a cold front to those of a warm front; furthermore, cyclonic disturbances develop easily on such fronts. Experience in forecasting along the Gulf Region has taught that wave developments are generally the rule in such cases.

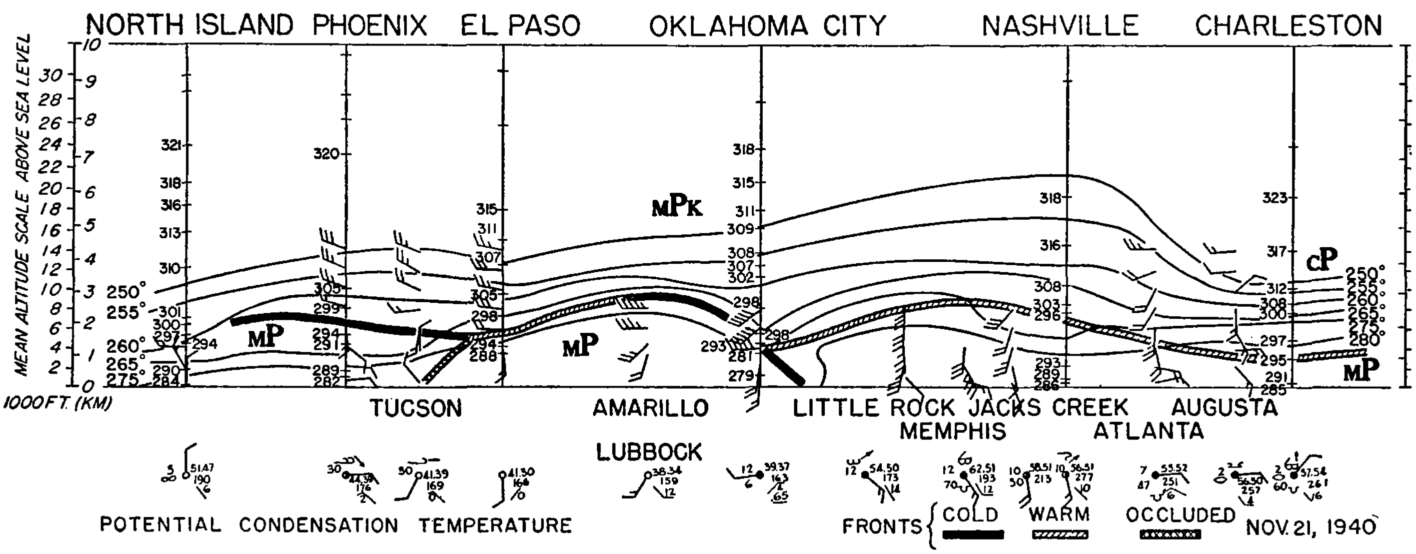

FIGURE 1.

Warm, moist, stable MTw air (maritime tropical air) lay to the south of the cold front along the East Texas coast, with specific humidity 14.7 grams per kilogram at the surface at Brownsville and extended to near 3 kilometers, with drier, cool, unstable air above (fig. 2). Over Texas was a weakening east-west high-pressure ridge, approximately 1017 mb., of MPK air with the specific humidity near 5 grams per kilogram from the surface to 4 kilometers, but cPw mixed with MPw westward to

[1] Bergeron, T., "Über die dreidimensional verknüpfende Wetteranalyse," *Geofysiske Publikasjoner*, Oslo, 1928, vol. V, No. 6.
[2] Willett, H. C., "American Air Mass Properties," *Massachusetts Institute of Technology Papers in Physical Oceanography and Meteorology*, vol. II, No. 2; June 1933.
[3] Showalter, A. K., "Further Studies of American Air-Mass Properties," MONTHLY WEATHER REVIEW, vol. 67, No. 7, pp. 204-218, July 1939.
[4] Pierce, C. H., "On the use of Vertical Cross Sections in Studying Isentropic Flow," MONTHLY WEATHER REVIEW, vol. 66, No. 9, pp. 266-267, September 1938.
[5] Rossby, C. G., "Isentropic Analysis," *Bulletin of the American Meteorological Society*, vol. 18, No. 6-7, p. 201, June-July 1937.
[6] Willett, H. C., "Discussion and Illustration of Problems Suggested by the Analysi, of Atmospheric Cross-Sections." Papers in Physical Oceanography and Meteorology, Massachusetts Institute of Technology, and Woods Hole Oceanographic Institutions July 1935: vol. IV, No. 2.
[7] Byers, H. R., "On the Thermodynamic Interpretation of Isentropic Charts," MONTHLY WEATHER REVIEW, vol. 66, No. 3, pp. 63-68, March 1938
[8] Pierce, *op. cit.*

[9] Norton, Grady, "Studying Weather Forecasting in the Lower Mississippi Valley" (unpublished).
[10] Petterssen, S., *Weather Analysis and Forecasting*, 1940.

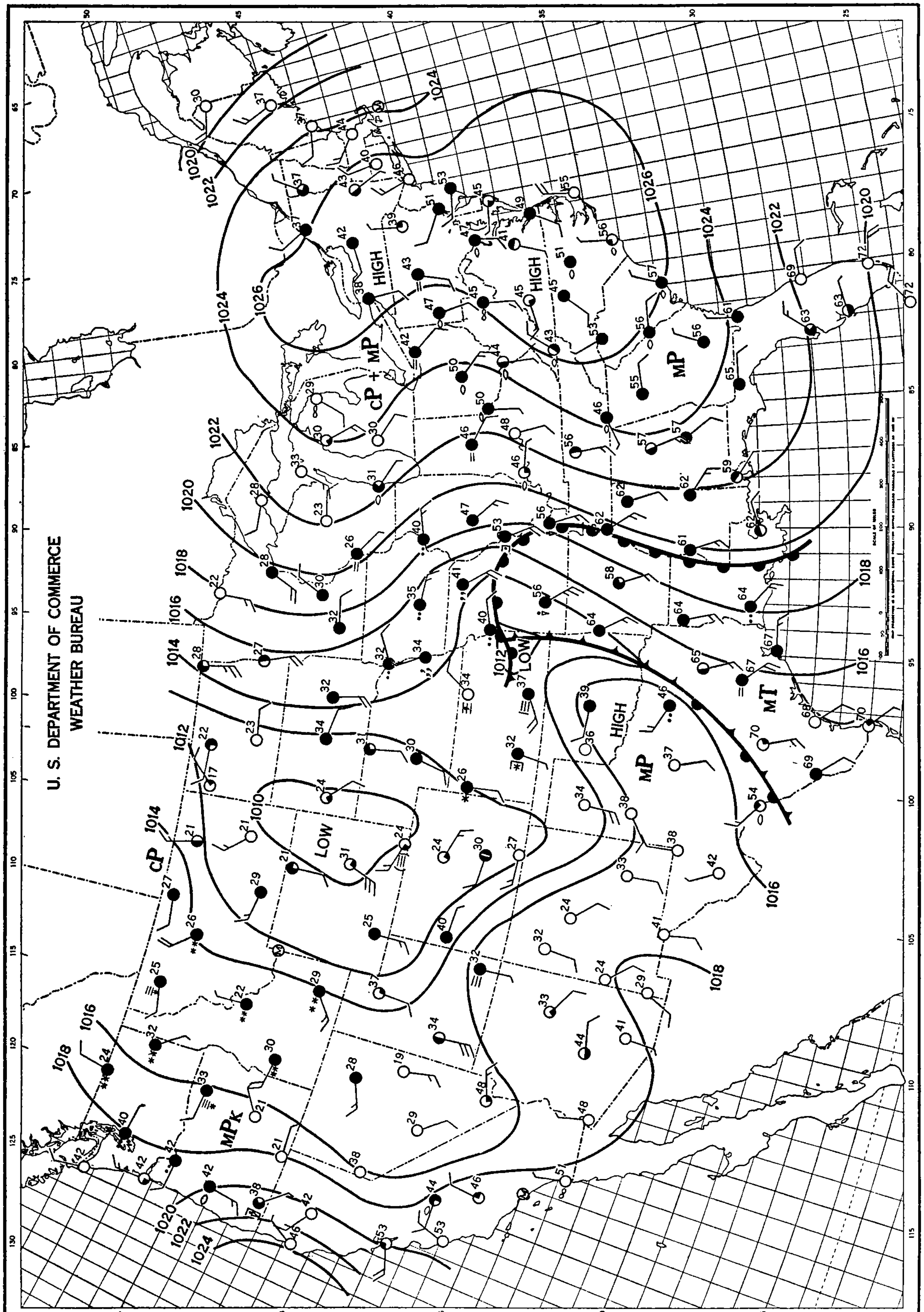

FIGURE 1a. 1:00 a. m., Nov. 21, 1940.

California, and very dry air above 2 kilometers west of El Paso, Tex., as shown by the soundings at El Paso and westward.

It will be noted on the cross section (fig. 2) that the air aloft between Brownsville and Waco, Tex., just to the west of the region where the heavy rains developed, was very moist and stable to about 2,500 meters and was rather dry and unstable above. This condition of "convective instability" is inducive to heavy rain showers once the air is lifted over a region; the air above the moist layer becomes increasingly unstable as it is forced upward, cooling at or near the dry adiabatic rate, while the lower level moist air cools much slower and near the pseudo-adiabatic rate. This condition plus the continuous inflow of moist air over southern Texas, from the south, for the following 3 days (November 22, 23, and 24) is shown graphically on the isentropic surface with a potential temperature of 298° in figures 11, 12, and 13. This potential surface is a very representative one as it was on an average at about 1 km., well above any surface inversions. The air aloft over the Southern Plateau States of New Mexico, Arizona, and west Texas, was very cold in the levels above 2,500 meters and very unstable. The inflow of the warm moist air northwestward into the region occupied by the shallow cold air on November 21, figures 1, 1a, and 2, resulted in a concentrated thunderstorm activity when the rain once began in the region of southeast Texas. The air aloft was becoming more and more unstable as is evident from the slow fall of potential temperature over the Brownsville region. With the approach of cold air from the Northern Plains States on November 22 (fig. 3a), the rains and thunderstorms over the Palestine, Tex., area began to intensify; and by November 23 (fig. 5a), a definite "wave" of low pressure seemed to be forming over a line from southern Arkansas to Waco, Tex., as an isobaric deformation was evident and rapidly falling tendencies of as much as 1.6 mb. were noted in southern Arkansas and northeast Texas. It has been observed in many other heavy-rain-type maps over southeast Texas, notably, December 1940, the spring of 1941, and October 29–31, 1941, that the heaviest rains are associated with that area where the "wave" begins to form, provided, of course, the moisture content is high, the intermediate and upper levels are unstable with respect to dry air and enough convergence is present to start the processes of condensation and precipitation.

After the "wave" of low pressure had developed strongly over southeast Texas November 25 (fig. 8a), the southerly current highly charged with moisture was cut off and replaced in the intermediate and high levels by a dry northwesterly current as shown on the isentropic chart of November 26 (fig. 14), and the rain stopped suddenly as a result of this on the afternoon of November 25.

The isentropic cross section (fig. 1) shows potential temperatures and isentropic condensation temperature isotherms, both in absolute temperature for each 5 degrees. From the slow increase of potential temperature with elevation, instability of the air is apparent above the cold surface layers immediately behind (to west) of the front. Although the cold front near McAlester, Okla., shows a slope of about 1 mile in 100 miles, the low condensation temperatures above 2 kilometers to the west and east of the cold front restrict the precipitation and clouds to a strip of approximately 100 miles between McAlester, Okla., and Fort Smith, Ark., extending northward and southward.

As shown on the north-south cross section (fig. 2), the rain covered an area from near Omaha, Nebr., to Waco, Tex. An example of the use of cross section for finding amount of lift necessary for condensation is as follows: The air over Brownsville, Tex., at 937 mb. had a temperature of 291° and an isentropic condensation temperature of 288°, a difference of 3° C. Since air cools approximately 1° C. per 100 meters, only 300 meters lifting was required for condensation. This is first realized near Waco, Tex., where the potential surfaces rise sharply enough above the cold front to produce precipitation. Although no observations were made within the cloud it is conceivable that the cloud deck was supercooled to freezing or below over the rain area, as was apparent in figure 1 over the Oklahoma City area. During this entire rain period the moisture increased steadily over south Texas, as seen on subsequent cross sections, starting with near 15 grams at Brownsville on the 21st and in-

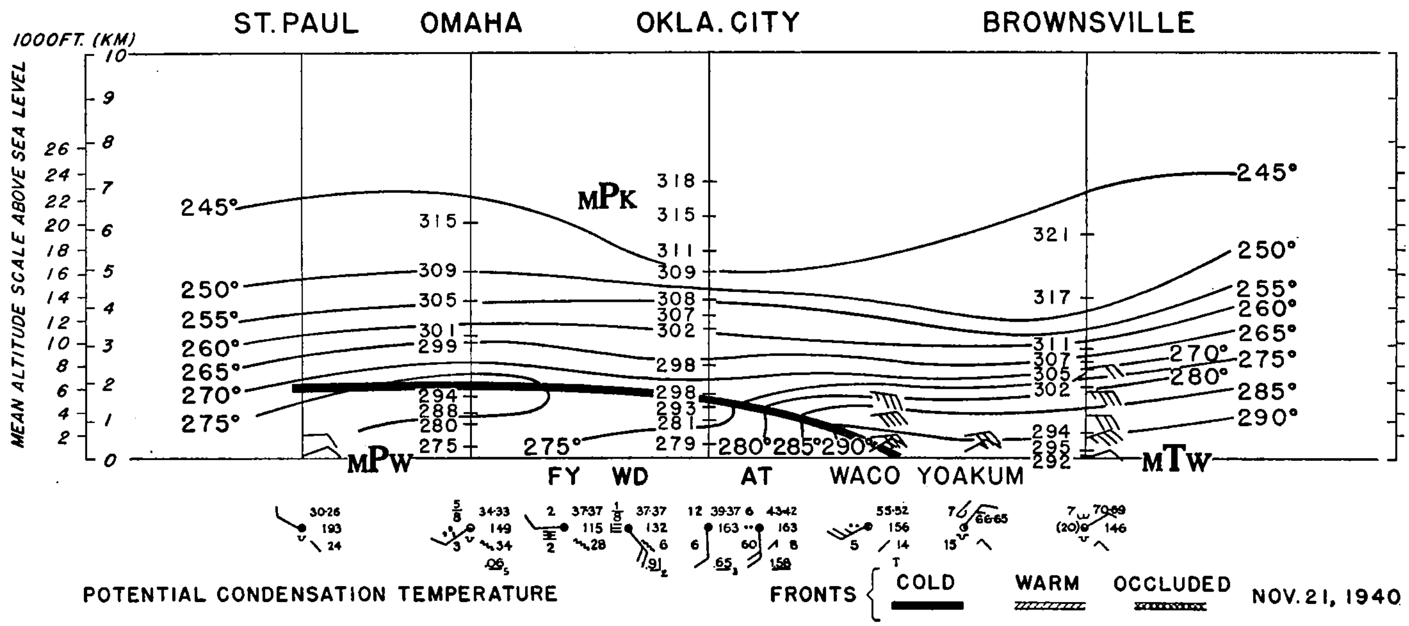

Figure 2.

creasing to near 18 grams per kilogram on the 23d, at the surface level.

During the night of November 22, moderate to severe thunderstorms and heavy rains occurred over southeast Texas as the warm, moist Gulf (mTk) air overran the cold air remaining at the lower levels in central southeast Texas. This area was where the cold front became quasi-stationary the day before, the 21st, a fact which is extremely significant as the mTw air to the south of the front was not displaced and later started northward, overrunning the stagnant, stable, cold, moist air. The quasi-stationary front over southeast Texas had advanced northwestward as a warm front to north central Texas. Light precipitation, mostly drizzle, as is usually the case, occurred over south and central Texas in the mTw air.

As shown on the east-west cross section (fig. 3), a flattening of the frontal (potential) surfaces caused subsidence and temporary clearing over Oklahoma. At the same time, as seen on the north-south cross section (fig. 4), unstable air was over the Dallas–Fort Worth, Tex., area and caused heavy precipitation in north central Texas, the warm, moist air continuing its northern trek.

The clearing, we find, for Texas is from a southwesterly direction; and the first clue is the ending of the rain along the Mexican border, near Del Rio, Tex., in particular.

By 7:30 p. m., November 23, the eastern part of the cold front in north Texas had moved to near Palestine, Tex., and the western portion to Del Rio, Tex. The cold air underrunning the warm air caused more rain all along the front, but not quite so heavy as in the afternoon and night of the 22d.

The cross section for November 23, 1940 (fig. 5), shows that a deepening of the cold air is occurring over the western portion of the east-west cross section and also over the north-south cross section (fig. 6), with cloud tops soaring high and rain increasing. The southerly winds over El Paso, Tex., changed to northerly in the lower levels during the night following this cross section, causing considerable rain in that area and to the eastward for the next 2 days.

The front that had advanced southeastward to central Arkansas extended southwestward to Del Rio, Tex., by the 1:30 a. m., E. S. T., map of November 24, 1940 (fig. 7a). This map is the turning point of the situation. As men-

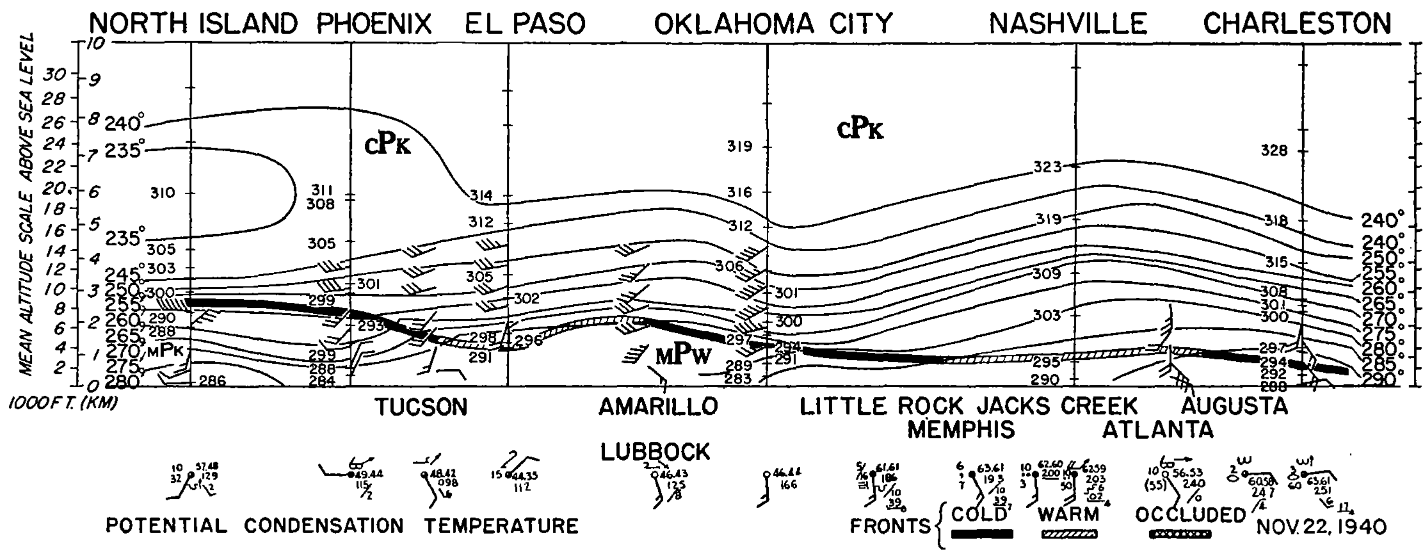

FIGURE 3.

tioned above, rapidly falling 3-hourly tendencies, usually over 1 mb., to the north or west of a point on a cold front portend a definitive wave formation. The fall of 2.4 mb. at Texarkana, Ark., is especially significant because the cold front changed to a warm front and moved northward. The 1:30 a. m. map of the 24th (fig. 7a) shows a continued definite inflow of the cold air to the west over the El Paso area, while the east-west cross section (fig. 7) shows a deepening of the cold air from the west and north to high levels.

This deepening of the cold moist air continued, and the wave over East Texas on the 24th developed into a deepening wave by the 1:30 a. m., E. S. T., map of the 25th (fig. 8a); the cross section (fig. 8) shows still more deepening cold air to the westward. By the 1:30 a. m., E. S. T., map of November 26 (fig. 9), a strong cyclone had developed and moved northeastward to southern Missouri. The rain ended suddenly over Louisiana and Texas behind the center; clearing occurred over a wide arc from the southwest, and more slowly in Oklahoma and Arkansas due to an occluded front in that region.

In conclusion, it is to be emphasized that the upper-air conditions over the southwest are especially important

It may be stated here that when a cold front tends to flatten out and become quasi-stationary over the Southern States, it should *never be ignored* for the reason that it may return as a warm front, sometimes generating a well-developed cyclone, as mentioned previously; this also holds true for the Gulf, and the regions along the southern Rockies.

By 1:30 a. m., E. S. T., November 23, 1940 (fig. 5a), the cold air that was over central Kansas on the 22d had advanced rapidly southward to the central Oklahoma area and was underrunning the warm air to the southward over West Texas. The large negative tendencies over Arkansas and Texas portended a movement of the front southward for the time being.

Norton (*op. cit.*) states with respect to a storm-center movement:

"Abnormal movements are indicated by the greatest fall being *north or west* of the center. If the storm has been blocked by a saddle for several days in Texas or the west Gulf region, then the old rule to look for a fall north of the center as indicating a breaking through, is a good one. In this case the storm increases in intensity and moves northeast, and clearing weather should be forecast as soon as a normal movement will carry the storm center from the district."

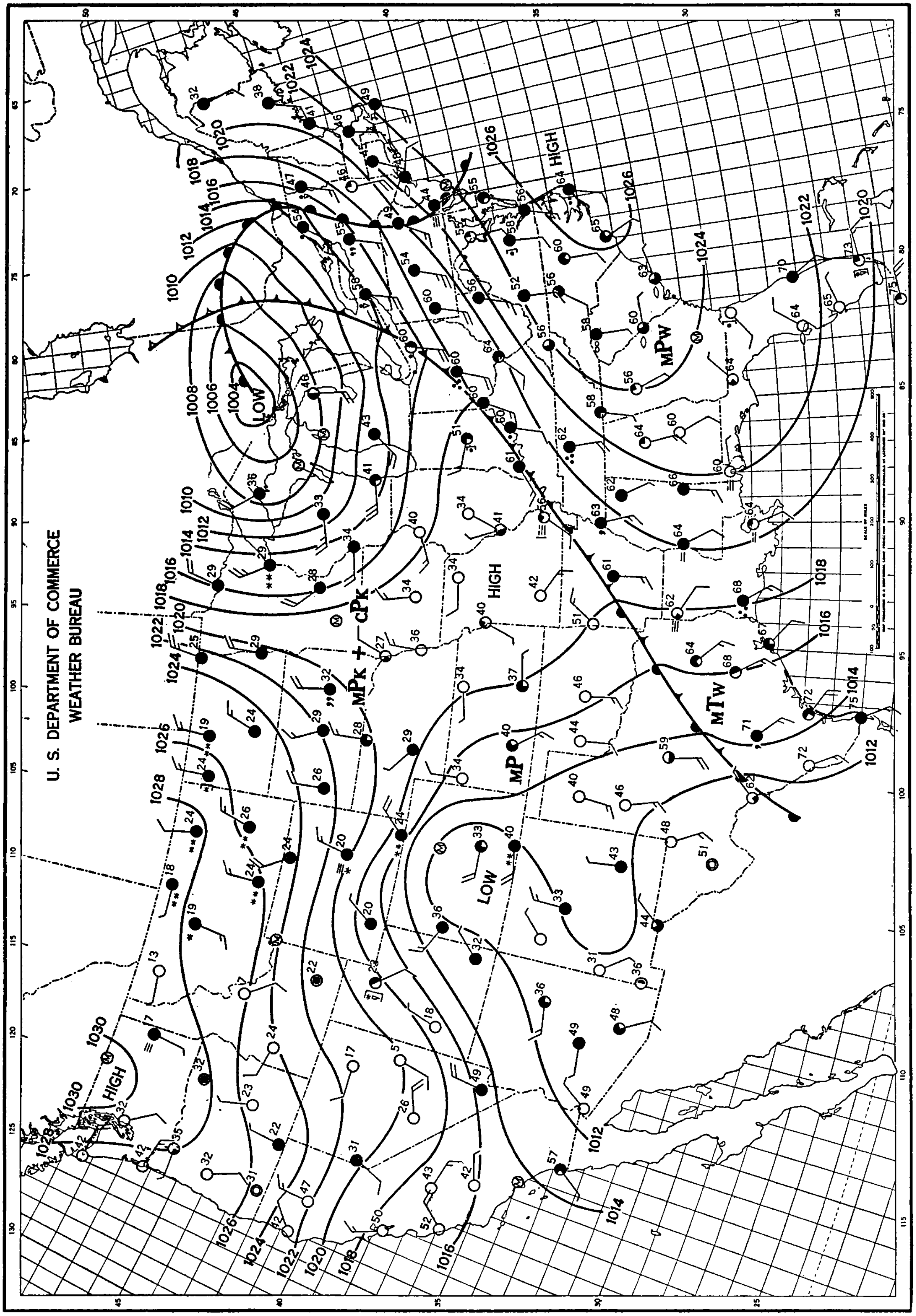

FIGURE 3a. 1:00 a. m., Nov. 22, 1940.

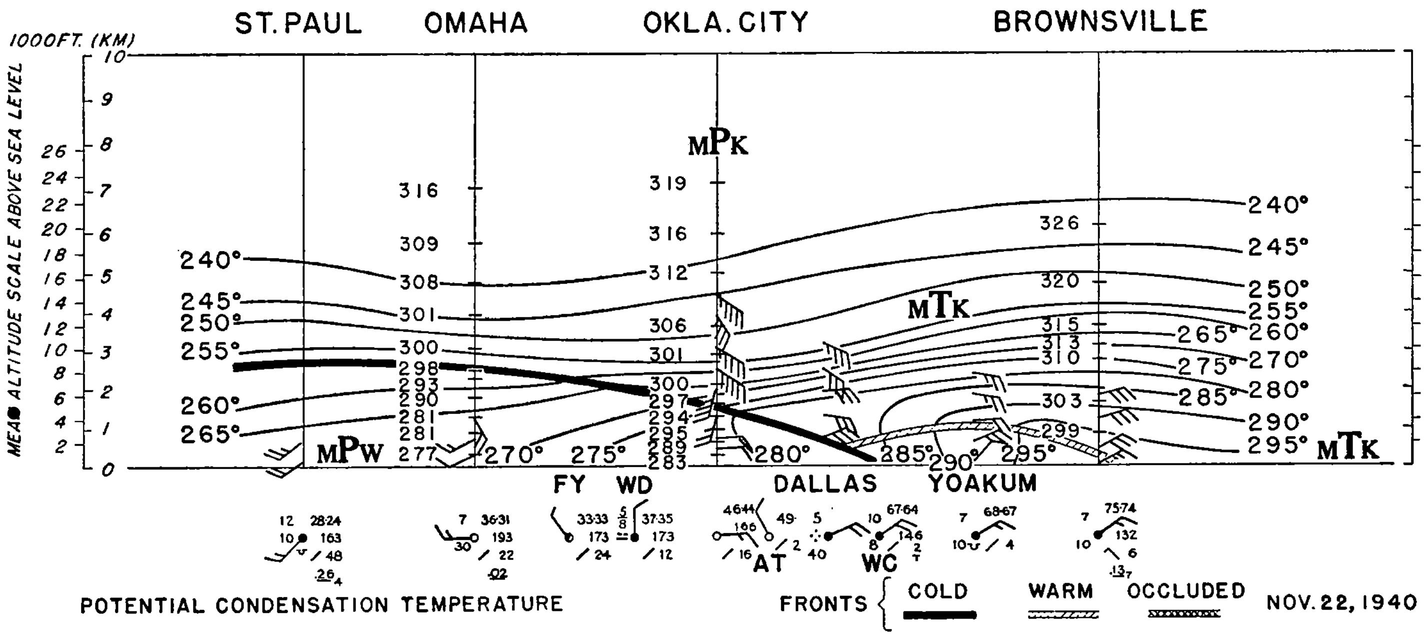

FIGURE 4.

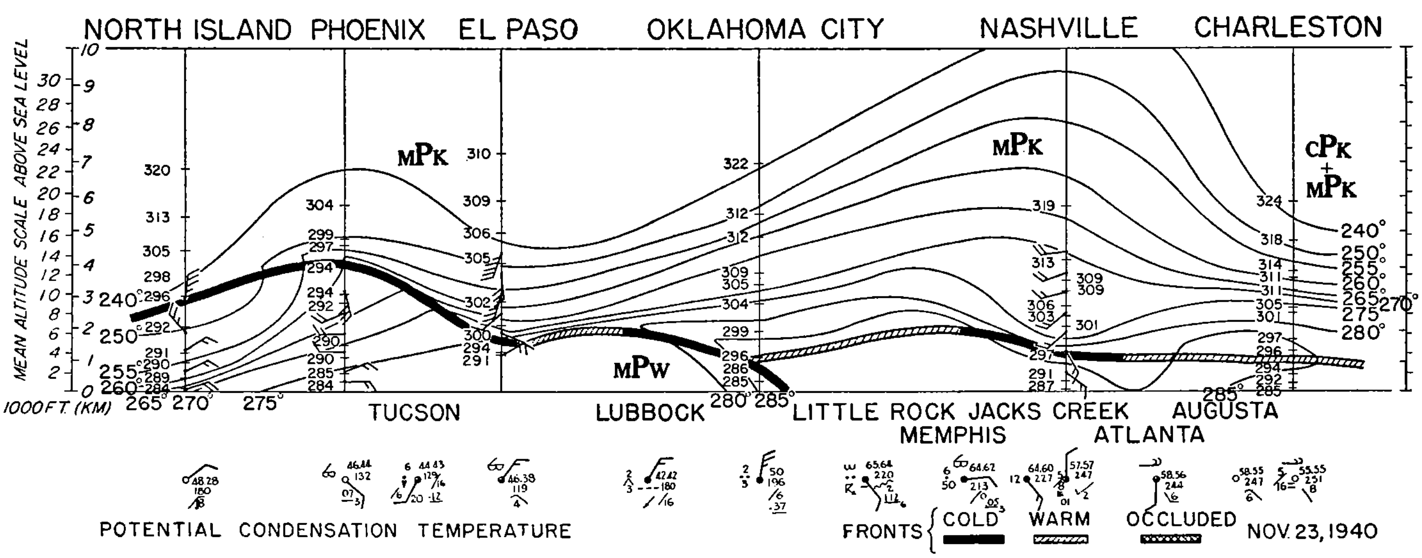

FIGURE 5.

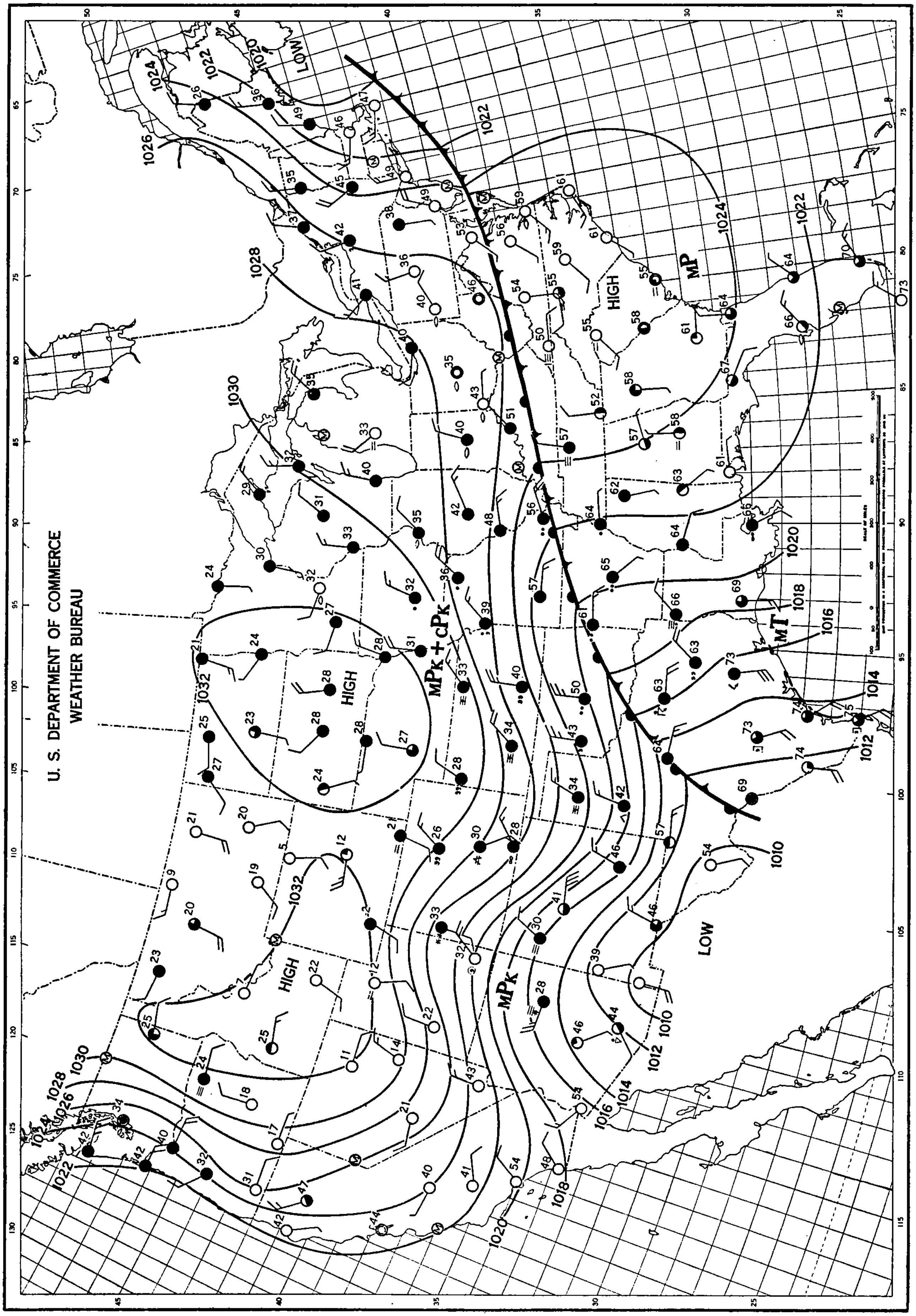

FIGURE 58. 1:00 a. m., Nov. 23, 1940.

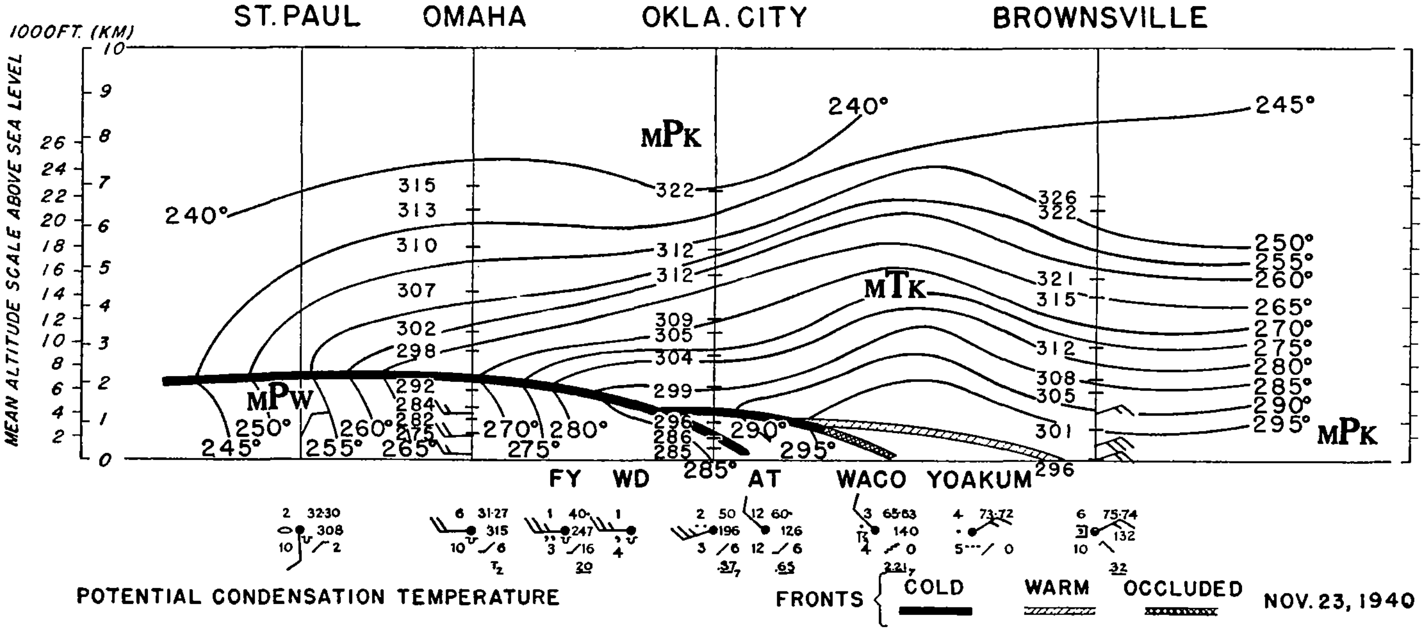

FIGURE 6.

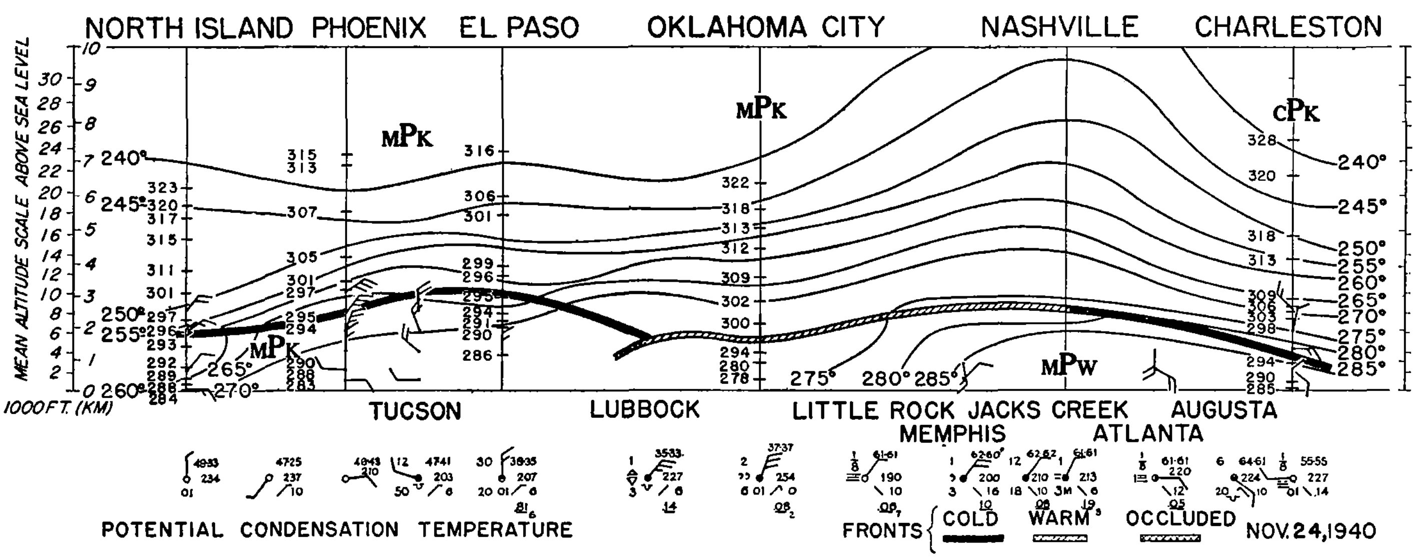

FIGURE 7.

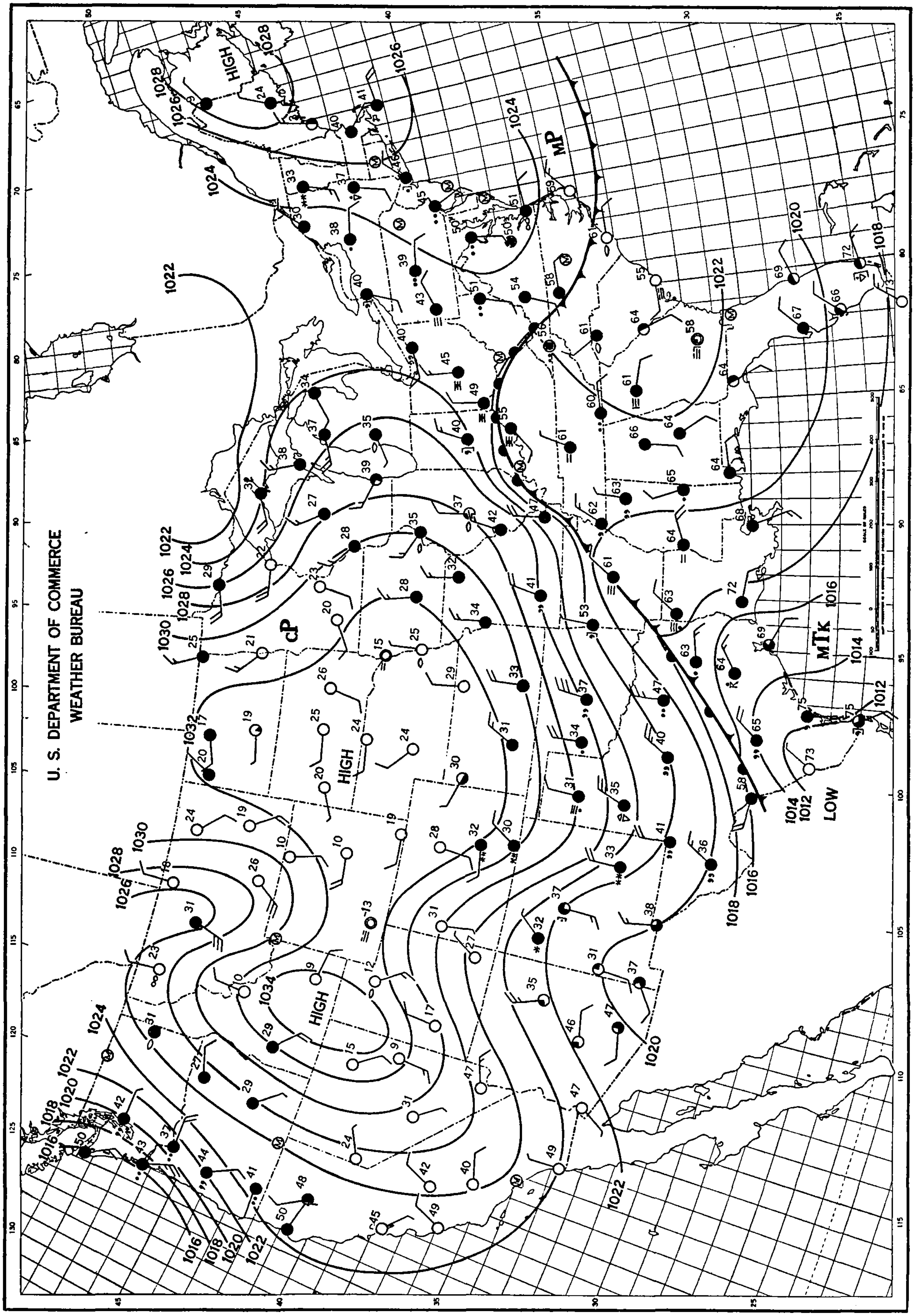

FIGURE 7a. 1:00 a. m., Nov. 24, 1940.

during a rain period. During the period of heavy precipitation in November 1940 (and also in December), the winds aloft in the vicinity of El Paso eastward to the Gulf were southerly, 30 to 50 miles an hour, at intermediate and high levels, and only began to turn southwesterly over El Paso on November 24 at 4 a. m., after which a general clearing began over Texas from the southwest. (This change in wind direction was indicated by pilot-balloon runs or by streamlines constructed from upper-air temperatures and pressures, the method employed by Vernon and Ashburn [11] being used.) As shown previously on the cross sections, the moisture content from upper-air on whether they are blocked to the eastward by a high-pressure area over the southeast or northeast. It is hoped that this paper, together with the synoptic maps, will aid in realizing the importance of wave developments possible along secondary cold fronts and quasi-stationary fronts in this region.

The action of the air flowing northward along upsloping isentropic surfaces will cause rain anytime with or without definite surface frontal action, provided moisture is sufficient. It is to be emphasized that in this region the isentropic nature of these quasi-stationary fronts is most important, and not their definite location at the

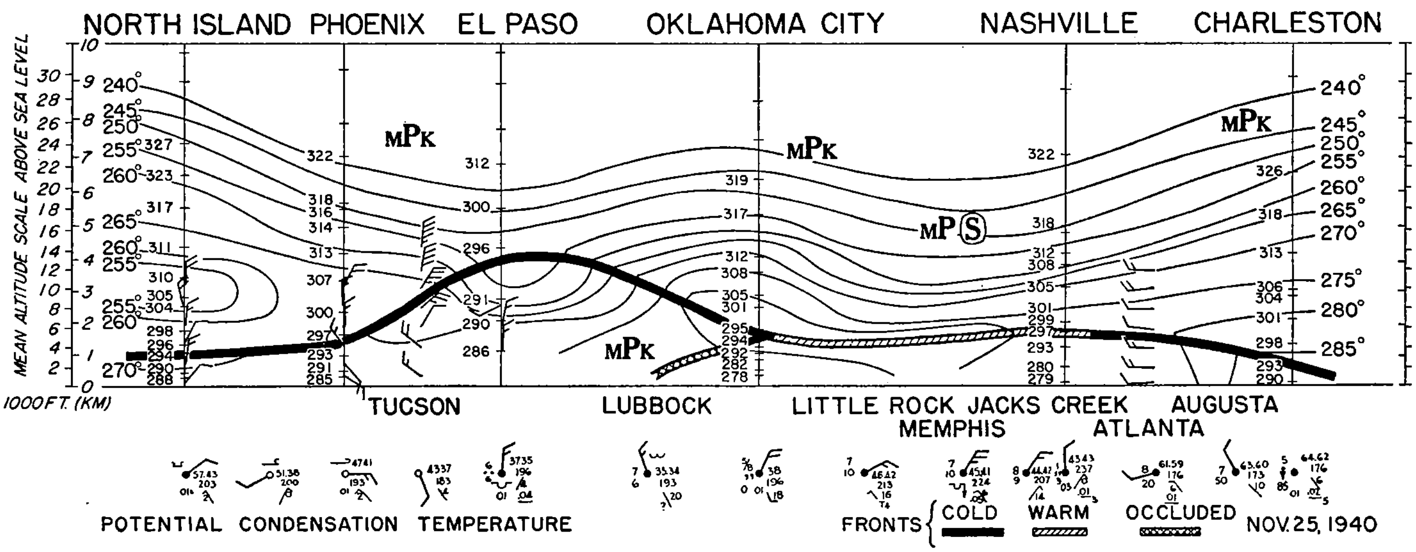

FIGURE 8.

soundings at Brownsville and El Paso, Tex., and Oklahoma City, Okla., increased rapidly after November 21, preceding the rain period.

The isohyetal chart (fig. 10) shows the heaviest rains over southeast Texas, where over 15 inches fell from November 18 to 27, 1940. This region was where the wave, which caused heavier rains, developed.

The accuracy of forecasts in this region depends primarily on ability to prognosticate wave developments. Then since nearly all low-pressure areas change in the south central Plains area to another directions of movement, the movements after development depend largely earth's surface, either in the Gulf or adjacent regions.

Potential temperatures and isentropic condensation temperatures enable use of isentropic cross sections for airway and local forecasts. Further, by drawing the east-west, north-south cross sections through a given area the slopes of the isentropic surfaces can be determined in any given direction; and consequently, when air-flow changes occur, the amount of lifting or subsidence will become immediately apparent.

---

[11] Vernon, E. N., and Ashbburn, E. V., "A practical method for computing winds aloft from pressure and temperature fields," MONTHLY WEATHER REVIEW, Vol. 66, No. 9, pp. 267-274, September 1938.

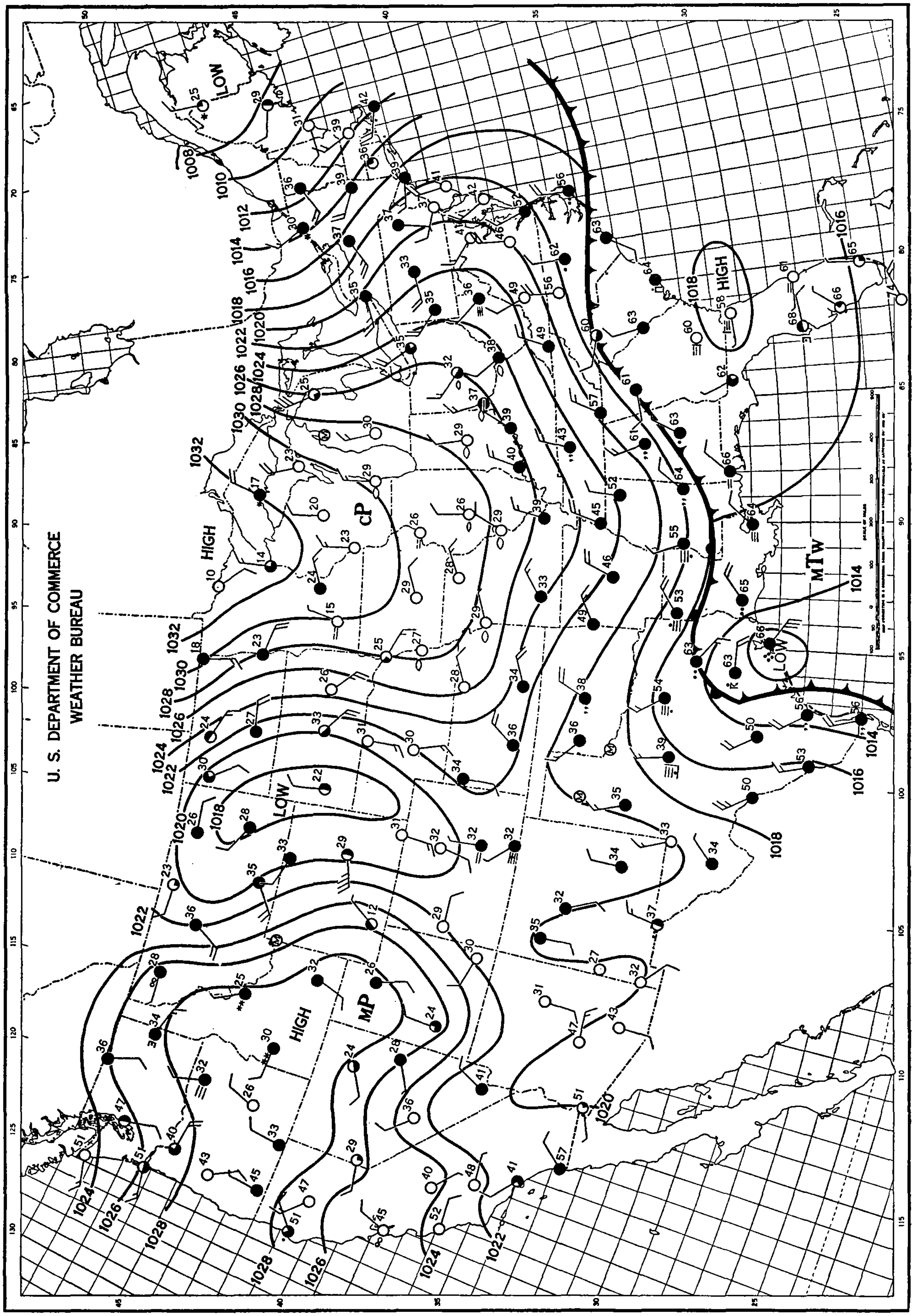

FIGURE 8a. 1:00 a. m., Nov. 25, 1940.

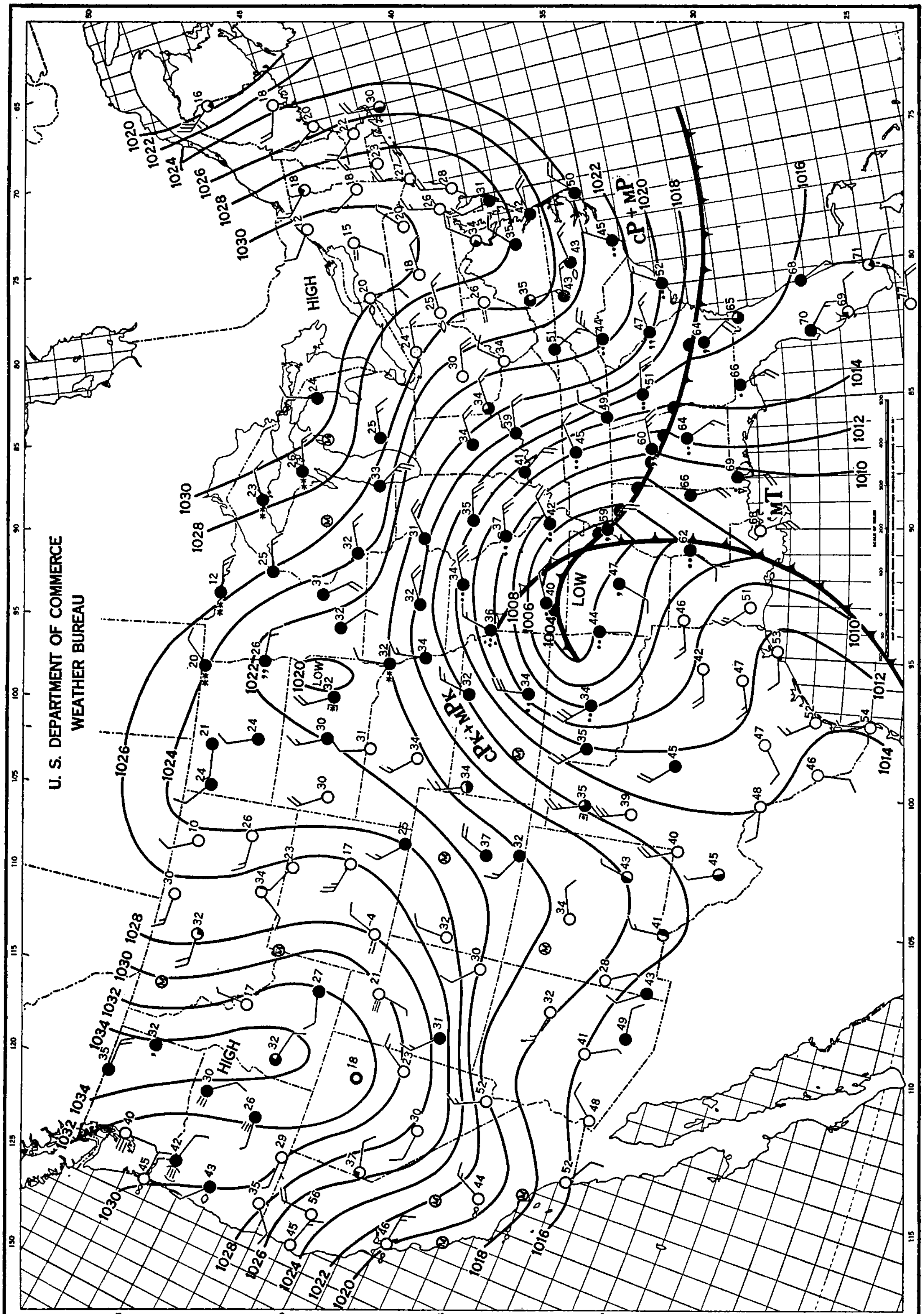

FIGURE 9. 1:00 a. m., Nov. 26, 1940.

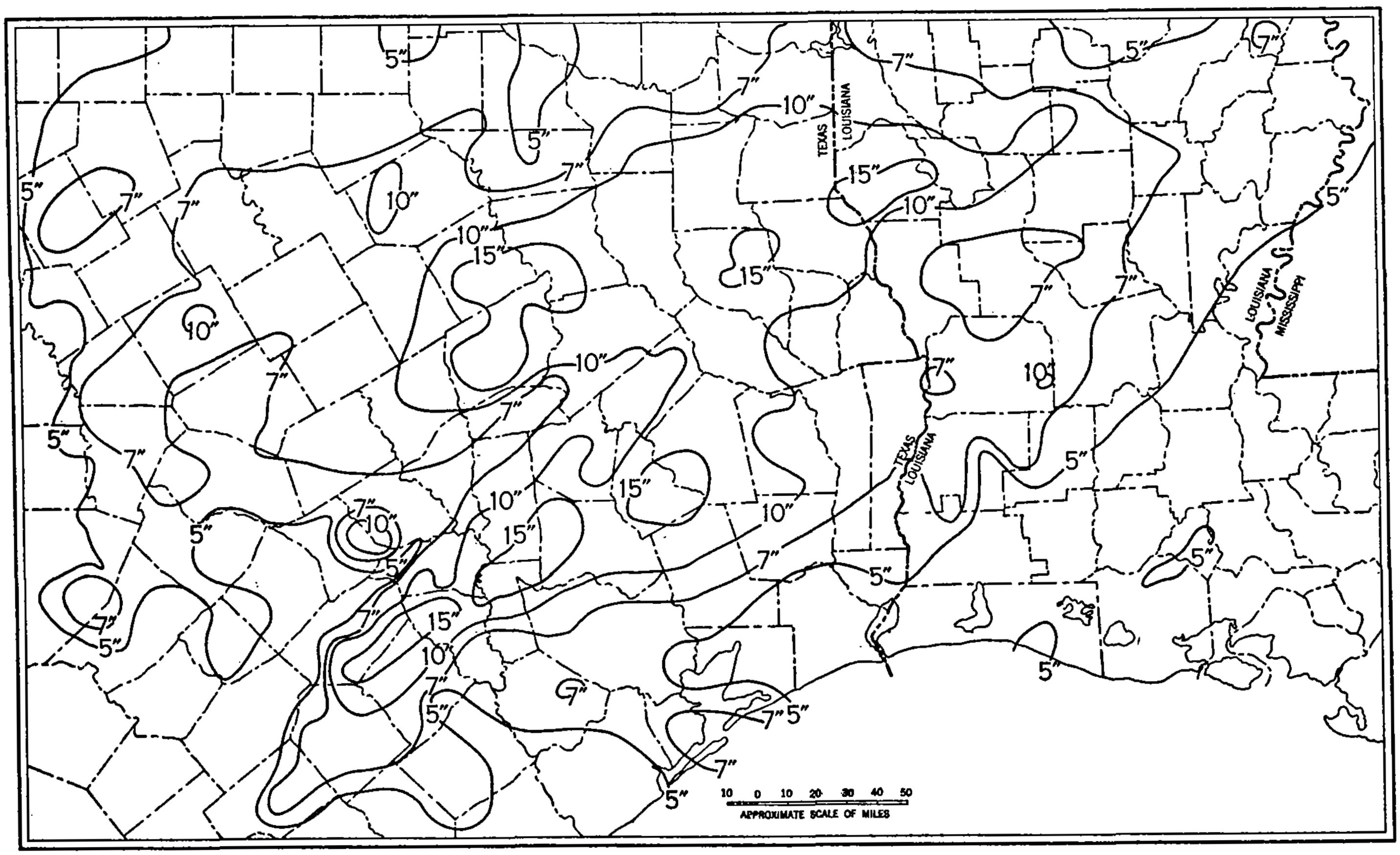
TEXAS
LOUISIANA
TEXAS
LOUISIANA
LOUISIANA
MISSISSIPPI
5"
7"
10"
15"
10 0 10 20 30 40 50
APPROXIMATE SCALE OF MILES

FIGURE 10.

MAP A1

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

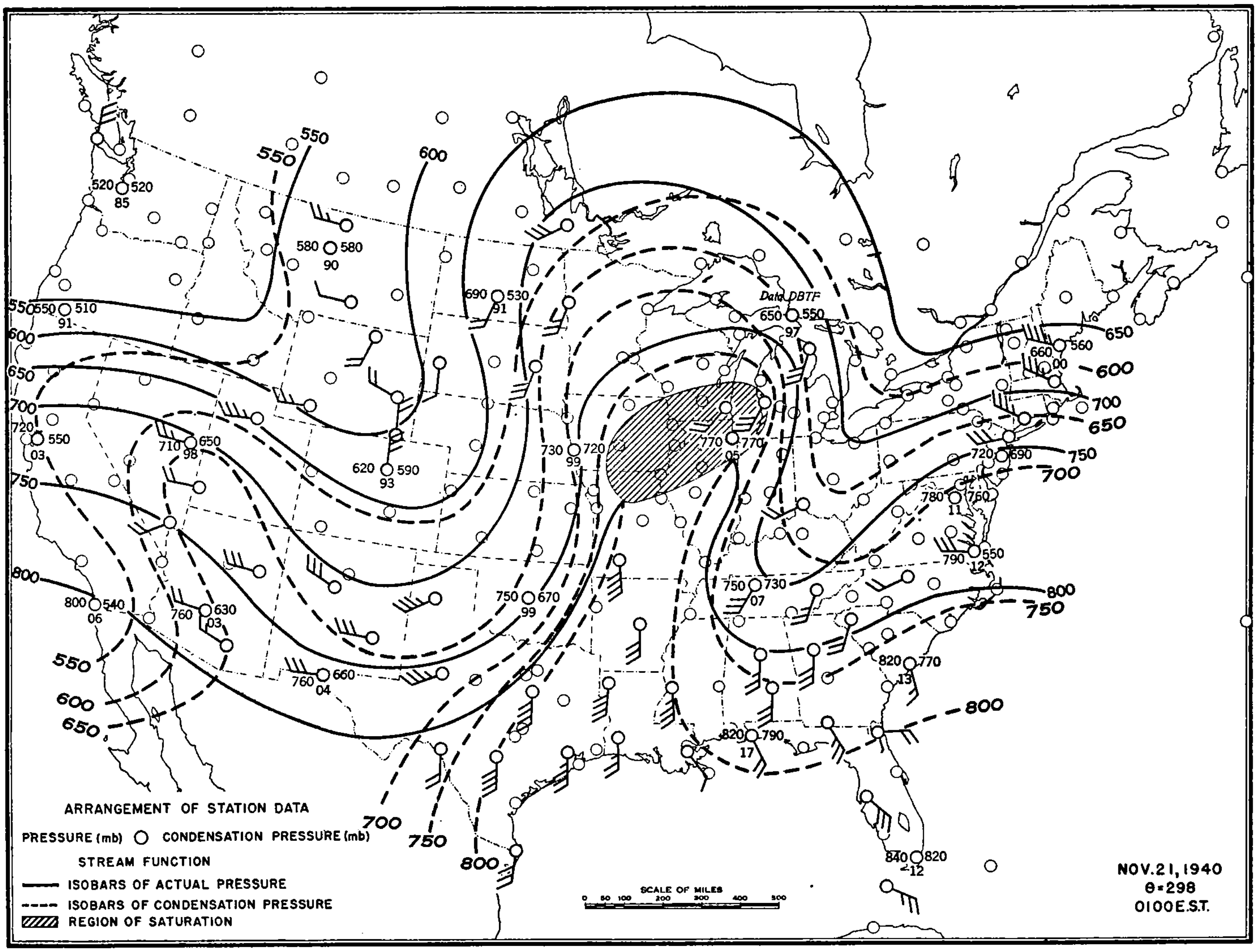

FIGURE 11.

MAP A1

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

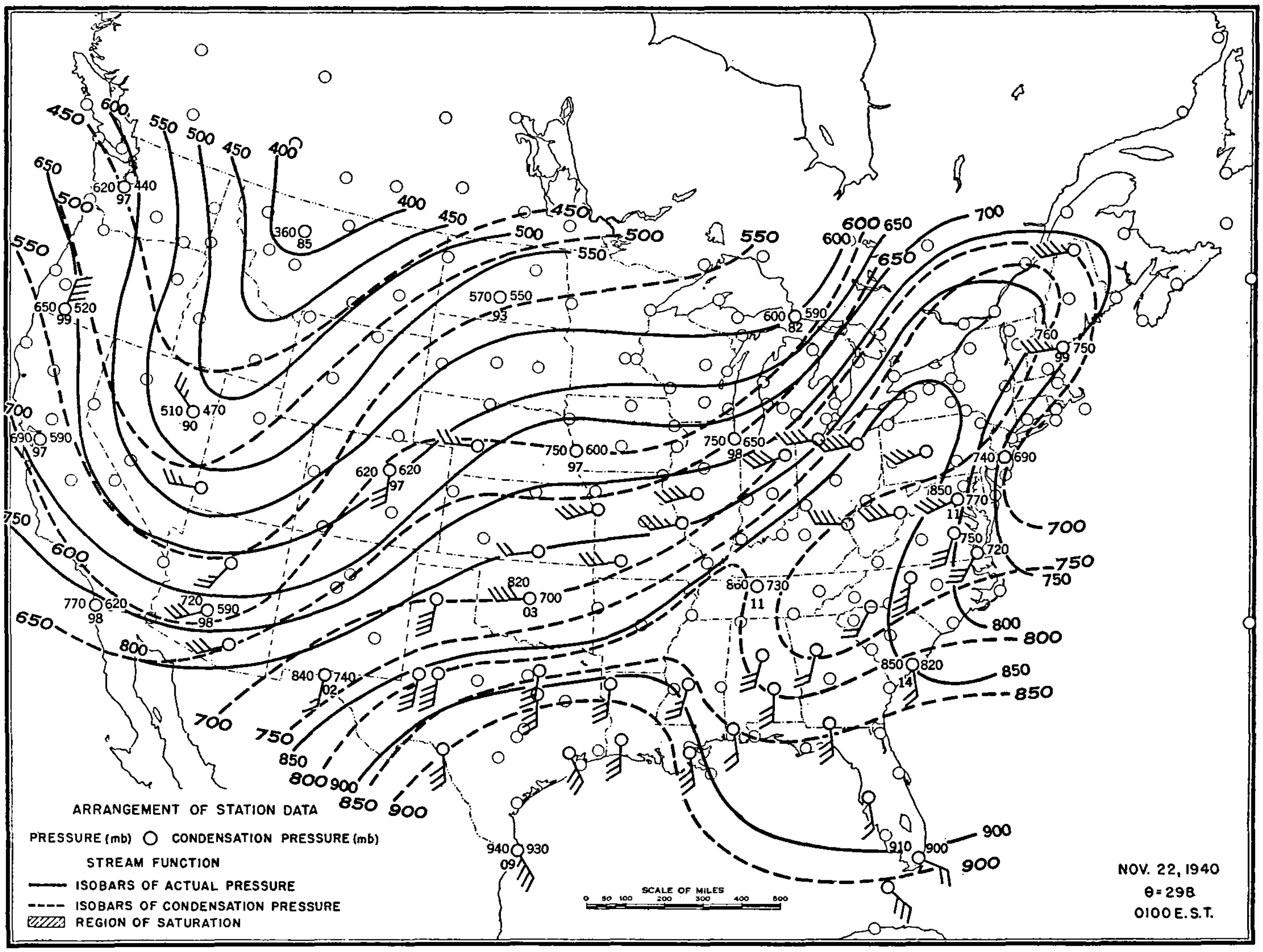

FIGURE 12.

MAP A1

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

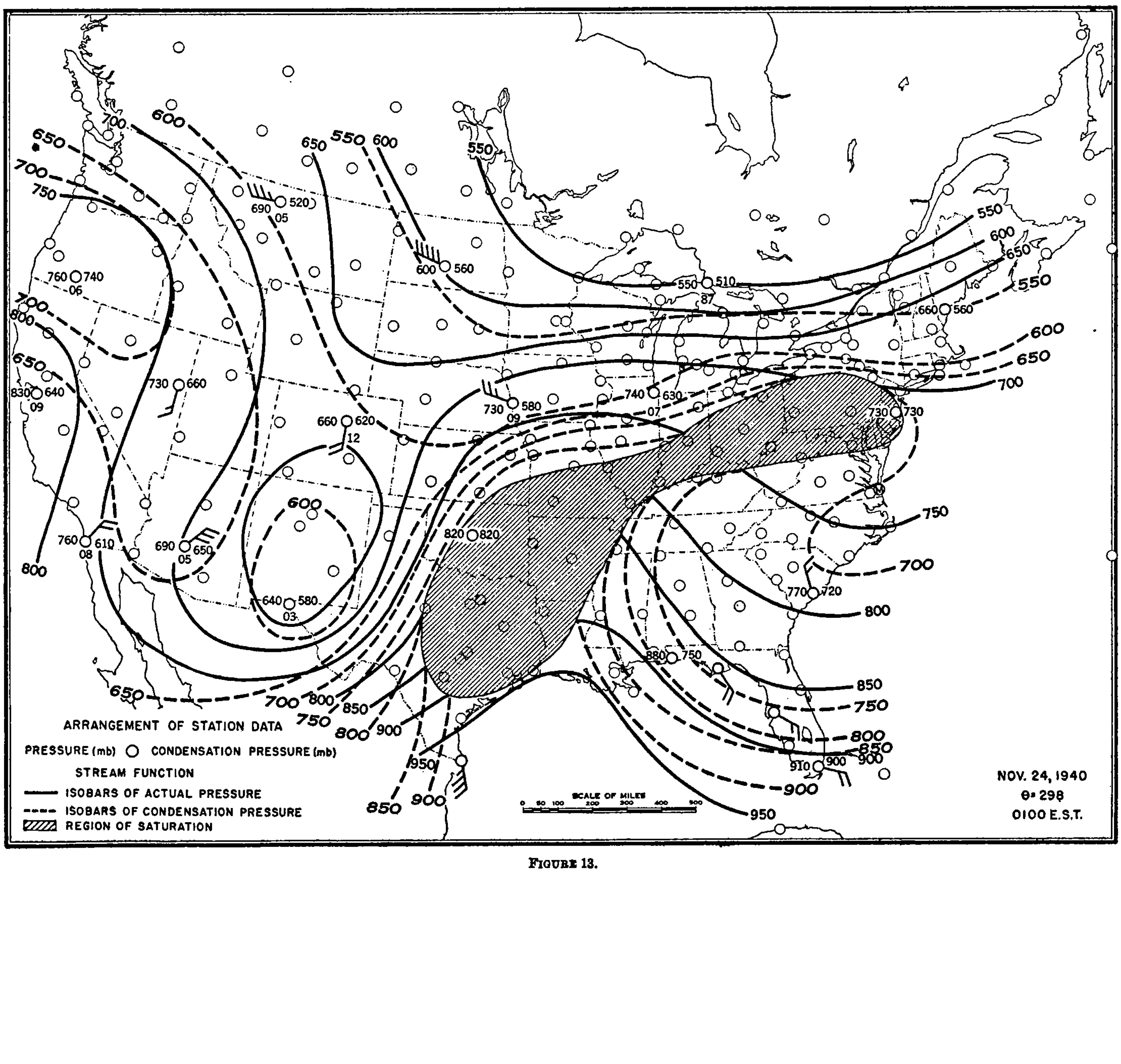

FIGURE 13.

MAP A1

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU

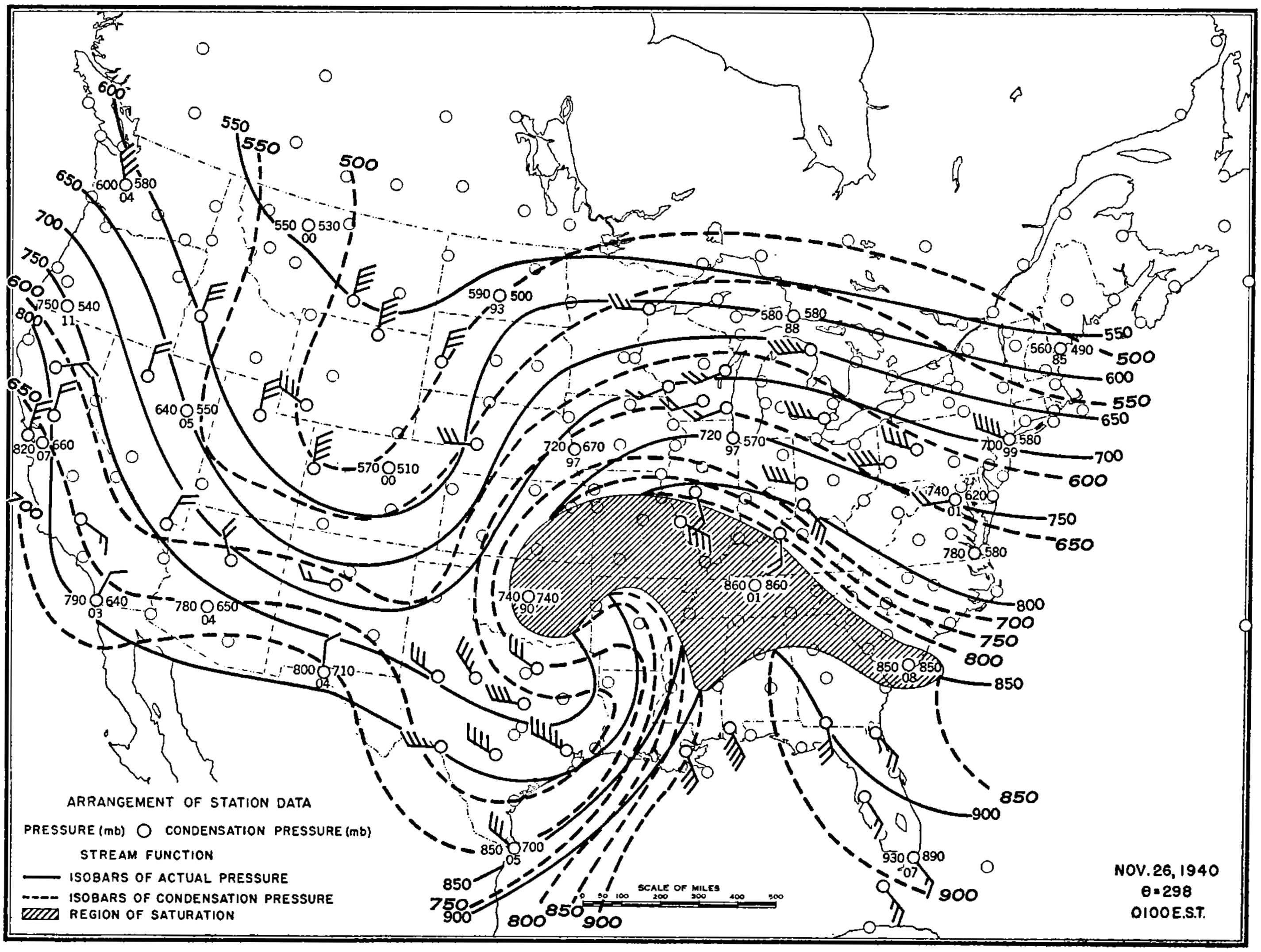

FIGURE 14.